
**Tractors and machinery for
agriculture and forestry — Electrical
high-power interface 700 V DC / 480 V
AC —**

**Part 3:
Safety requirements**

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*.

This document is intended to be used in conjunction with ISO 23316-1, ISO 23316-2, ISO 23316-4, ISO 23316-5 and ISO/FDIS 23316-6.

A list of all parts in the ISO 23316 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of the ISO 23316 series is to provide design and application standards covering implementation of electrical high-power interface with a nominal voltage of 700 V DC/480 V AC for agricultural and forestry machinery.

Conformance to the ISO 23316 series is determined when applicable requirements from all parts of the ISO 23316 series are met.

It is permitted for partial systems or components to conform with the ISO 23316 series by applying all applicable requirements, e.g. for the plug, receptacle, or inverters, on a tractor or implement.

NOTE For example, if a DC-mode only HPI is provided, it is not necessary to conform with ISO 23316-4 describing AC-mode, as it is not applicable. If an AC-mode only HPI is provided, it is not necessary to conform with ISO 23316-5 describing DC-mode, as it is not applicable.

The ISO 23316 series specifies physical and logical interface requirements that provide interoperability and cross compatibility for systems and equipment operating at nominal voltages of 700 V DC/480 V AC.

ISO 23316-1 describes the general purpose and structure of standards in the ISO 23316 series.

The structure of safety standards in the field of machinery is as follows:

- type-A standards (basis safety standards) giving basic concepts, principle for design, and general aspects that can be applied to machinery;
- type-B standards (generic safety standards) dealing with one safety aspect or one type of safeguards that can be used across a wide range of machinery:
 - type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);
 - type-B2 standards on safeguards (e.g. two-hands controls, interlocking devices, pressure sensitive devices, guards);
- type-C standards (machinery safety standards) dealing with detailed safety requirements for a particular machine or group of machines.

This document is a type C standard as stated in ISO 12100.

When provisions of this type C standard are different from those which are stated in type A or B standards, the provisions of this type C standard take precedence over the provisions of the other standards for machines that have been designed and built according to the provisions of this type C standard.

The machinery concerned and the extent to which hazards, hazardous situations and events are covered are indicated in the scope of this document.

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Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC —

Part 3: Safety requirements

1 Scope

This document describes the general safety requirements and guidance for the electrical high-power interface (HPI) in the ISO 23316 series.

The following topics are not within the scope of this document:

- service, maintenance, and related diagnostics;
- functional safety;
- control strategies for high power supply systems (PS) and load consumption systems;
- application-specific strategies and operational modes;
- component design;
- energy storage systems, e. g. supercapacitors or batteries;
- multiple electrical power supplies to a common DC-link.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6469-3, *Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety*

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 14990-1, *Earth-moving machinery — Electrical safety of machines utilizing electric drives and related components and systems — Part 1: General requirements*

ISO 16230-1:2015, *Agricultural machinery and tractors — Safety of higher voltage electrical and electronic components and systems — Part 1: General requirements*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water, and access*

ISO 23316-1, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 1: General*

ISO 23316-2, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 2: Physical layer*

ISO 23316-4, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 4: AC operation mode*

ISO 23316-5, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 5: DC operation mode*

ISO/FDIS 23316-6¹⁾, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 6: Control-communication*

IEC 60204-1:2016, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and ISO 23316-1 apply. ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org>

4 Safety requirement specifications

4.1 General

The HPI shall only be used in systems where the overall VC-B2 system is fulfilling the safety requirements of ISO 16230-1 or a comparable standard, such as ISO 6469-3, IEC 60204-1 or ISO 14990-1.

NOTE Mating with general purpose connectors has been discouraged by use of a very specific HPI physical interface, which is addressed in ISO 23316-2. The HPI is not known to be able to mate to any other connector.

[Table A.1](#) in [Annex A](#) references key safety requirements from the other parts of the ISO 23316 series.

4.2 Break away function

HPI connectors when mated shall provide a break away feature to minimize electrical hazards caused by damage of the cable and connector [e.g. in case the mechanical coupling between supply system and the consumer system (CS) has been lost while energized or while driving a tractor away from an implement].

4.3 Cable design

The cable shall be designed appropriate to the environment. The cables attached to the plug and receptacle shall be installed in a way that:

- moisture does not penetrate the rear of connector according to ISO 20653, IPX9K for water jets.
- is in accordance with ISO 16230-1:2015, Clauses 7 and 8.

Exception: The conductors need not be identified at the connector termination if permanently terminated to the connector:

- shield current does not exceed the limits of the connector.

NOTE ISO 14982 addresses electromagnetic compatibility (EMC) testing for Ag tractors and machinery used for agriculture and forestry in general.

1) Under preparation. Stage at the date of publication: ISO/FDIS 23116-6:2023.

4.4 Cable colouring

The power cables shall have an orange outer coating, per ISO 16230-1:2015, Clause 7.

NOTE Specifications of the orange colour are given in standards in the US (8.75R5.75/12.5) and in Japan (8.8R5.8/12.5) according to the Munsell colour system.

4.5 System design / general aspects

4.5.1 VC-B2 electrical system type

The connector shall provide galvanic isolation between the equipotential bonding and power conductors.

NOTE For Ag tractors and machinery used for agriculture and forestry, per ISO 16230-1, the overall electrical VC-B2 system (supply system and consumer system) is required to be an IT system.

4.5.2 Protection of persons against electric shock

Protection measures as described in ISO 16230-1:2015 Clause 5 (e.g. double insulation, reinforced insulation, protective barriers, or enclosures, etc.) shall be used for supply system and consumer system.

4.5.3 Automatic shutdown

4.5.3.1 Disconnect

The voltage shall reduce after the interlock is broken to less than VC-B within 1 s, unless a risk assessment is conducted to determine risks are adequately addressed. The risk assessment shall address:

- the risk to the bystander for electric shock from the cable and connector reaching water on the ground;
- energy on the consumer side which cannot be dissipated in that time.

Since the requirements in 4.2 can be insufficient for break-away, in some situations to prevent damage to the terminals, manual instructions shall indicate that inspection is required after a break-away event.

NOTE The terminals are designed to comply with IPXXB (see ISO 23316-2) indicating that the risk of direct contact is sufficiently addressed.

4.5.3.2 Severed cable

In the event of a severed VC-B2 cable, the voltage shall reduce to less than VC-B within 1 s, unless a risk assessment is conducted to determine risks are adequately addressed.

4.5.4 HPI system power coordination

The HPI control (HPI-C) and HPI master control (HPI-MC) together shall control the voltage on the class VC-B2 conductors according to the requirements of ISO 16230-1 such that the cable and components connected to the power conductors are adequately protected.

Reversing the direction of electrical power flow from the consumer system to the supply system is permitted (e.g. temporarily reversing for implement braking) provided the same conditions in the above paragraph are met.

4.5.5 HPI system insulation monitoring and coordination

If an insulation monitoring system is used, the details of coordination defined in ISO/FDIS 23316-6:— shall be referred to.

NOTE Continuous insulation monitoring of systems is not mandated within ISO 16230-1.

4.5.6 Bonding of exposed conductive parts

The exposed conductive parts utilized in the bonding path [e.g. motor housings and power converter (PC) enclosures] shall be galvanically connected to the protective bonding conductor (PBC) to avoid dangerous potentials due to failures of insulation. See [Figure 1](#). The intent of the word "exposed" within this document is in regard to parts more accessible than IPXXB per ISO 20653.

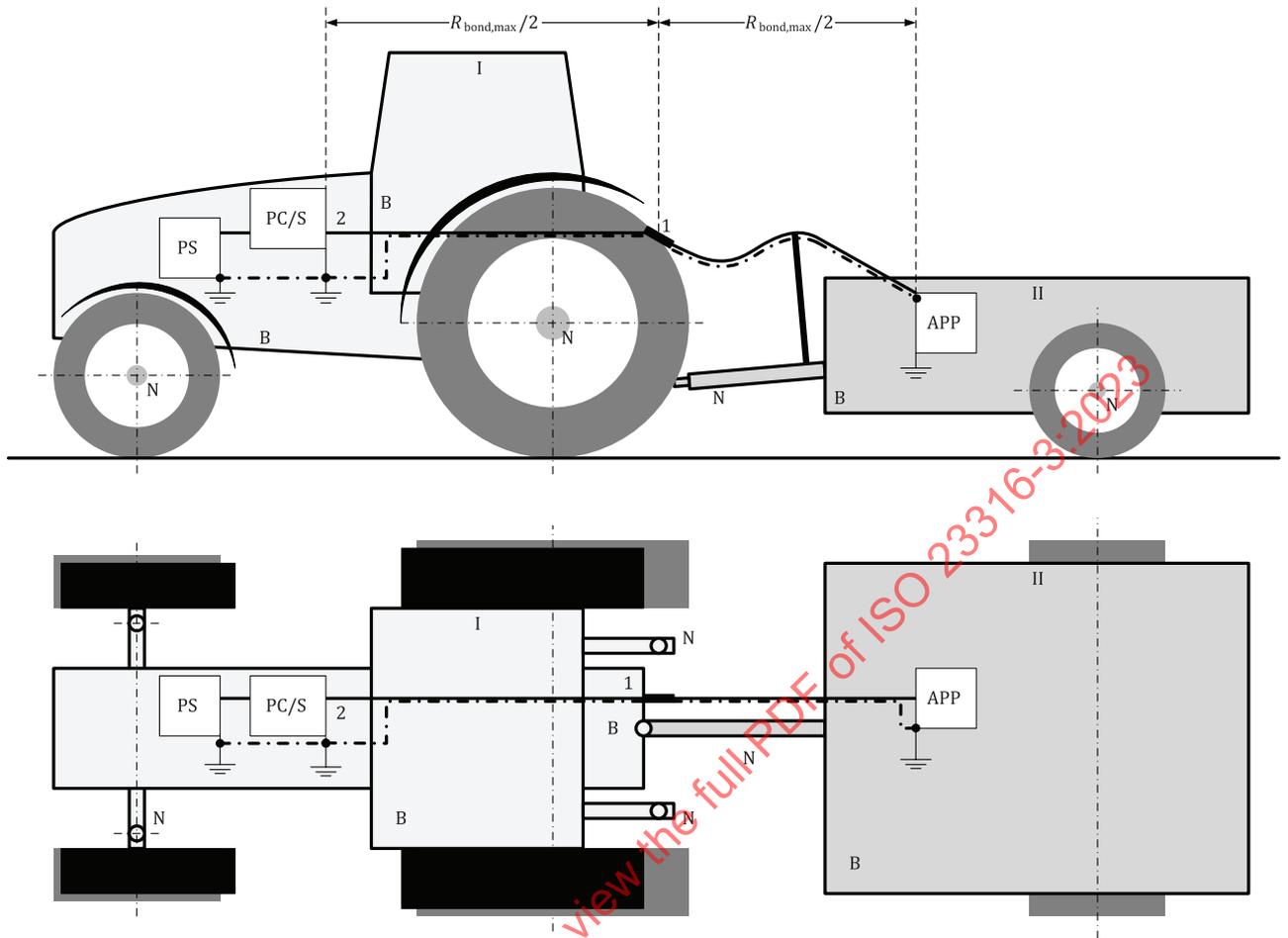
Conductive parts are only considered to be exposed conductive parts of the bonding path, if utilized to meet bonding requirements such as conductivity and conductor size, even if the parts are galvanically connected to the PBC. For example, hitches and draw bars, unless used to meet bonding requirements, are not considered an exposed conductive part of the bonding path. See [Figure 1](#).

4.5.7 Protective bonding conductor of the connected machinery

For two pieces of machinery connected by an HPI system (e.g. tractor and implement), a distance of 2,5 m shall be taken into account for the selection of two simultaneously exposed conductive parts of the bonding path on both pieces of machinery, to address the resistance requirements found in ISO 16230-1:2015, 5.5.1. Verification of these resistance values shall take into account all positions of the mated systems. See [Figure 2](#).

To simplify the measurement, and not require both pieces of machinery be physically mated during the test, the resistance value may be evenly split between the two pieces of machinery. If the HPI system is mated and even splitting is utilized, then the resistance shall be measured from HPI PBC terminal to any exposed conductive parts of the bonding path on either of the pieces of machinery less 2,5 m from each other. Each measured resistance shall be less than half the allowed resistance of 0,1 ohms, or less than 0,05 ohms. See [Figure 1](#).

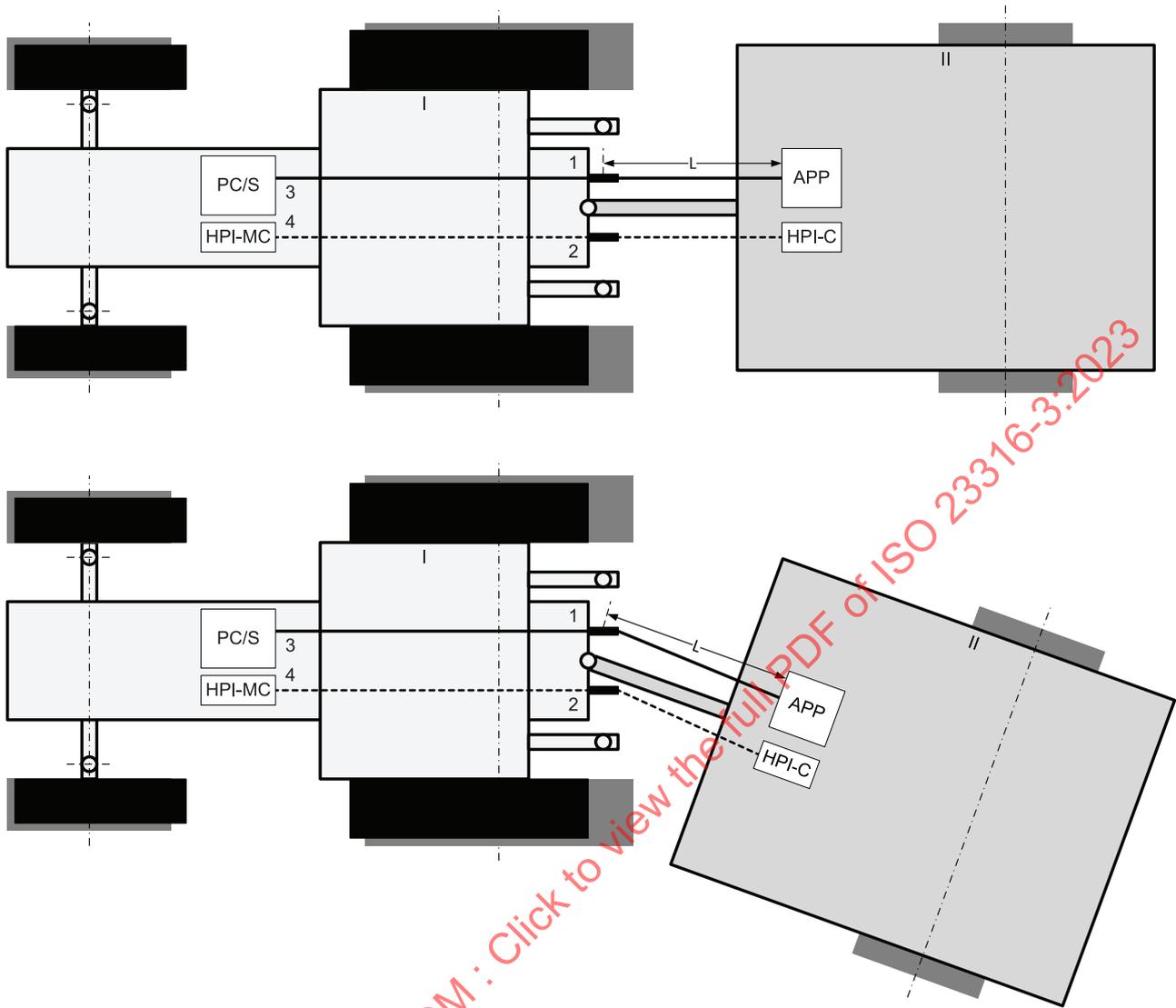
NOTE This method is valid due to the very low resistance requirements of the mated bonding terminals defined in ISO 23316-2:2023, 4.6.



Key

- APP application (e.g. inverter (INV), motor)
- B bonding parts (examples for conductive parts likely contributing to the bonding system)
- HPI-C high power interface – control
- HPI-MC high power interface – master control
- N non-bonding parts (examples for conductive parts likely not contributing to the bonding system)
- PC/S power converter/switch
- PS power source (e.g. rectifier, generator)
- I supply system
- II consumer system
- 1 high power interface
- 2 power lines
- $R_{bond, max}$ maximum allowed bonding resistance
- power connection
- - - - protective bonding conductor (PBC)

Figure 1 — PBC path of the connected machinery



Key

APP	application (e.g. inverter, motor)
HPI-C	high power interface – control
HPI-MC	high power interface – master control
PC/S	power converter/switch
I	supply system
II	consumer system
1	high power interface
2	ISOBUS connector
3	power lines
4	ISOBUS
L	distance between exposed conductive parts
—	power connection
-----	signal connection

Figure 2 — Power and signal connections